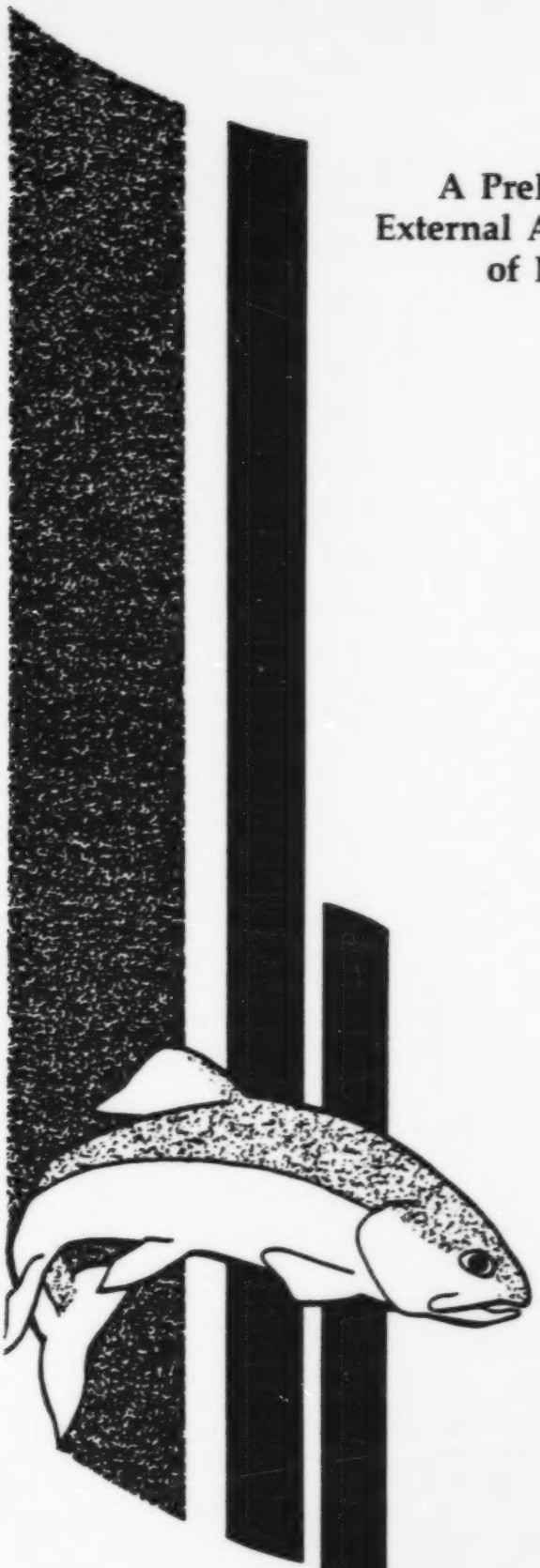

A Preliminary Assessment of the Effect of External Abrasion on the Smolt-to-Adult Survival of Net-Pen Cultured Steelhead Trout

by

PAT A. SLANEY
BRUCE R. WARD
LINDA BERG

FISHERIES TECHNICAL CIRCULAR No. 88

1990

Province of British Columbia
Ministry of Environment

Fisheries Technical Circulars frequently contain preliminary data, and conclusions based on these may be subject to change. Reports may be cited in publications but their manuscript status (M.S.) should be noted.

A PRELIMINARY ASSESSMENT OF THE EFFECT OF EXTERNAL ABRASION ON THE SMOLT-TO-ADULT SURVIVAL OF NET-PEN CULTURED STEELHEAD TROUT

Pat A. Slaney[1]
Bruce R. Ward[1]
Linda Berg[2]

[1]Ministry of Environment, Recreational Fisheries Branch,
Fisheries Research and Development Section,
2204 Main Mall, University of British Columbia,
Vancouver, B.C. V6T 1W5

[2]Department of Fisheries and Oceans,
555 West Hastings Street,
Vancouver, B.C., V6B 5G3

Fisheries Technical Circular No. 88
1990

Canadian Cataloguing in Publication Data 90-04748/

Slaney, P. A.
A preliminary assessment of the effect of external abrasion on the smolt-to-adult survival of net-pen cultured steelhead trout

(Fisheries technical circular, ISSN 0229-1150 ; no. 88)

Includes bibliographical references.
ISBN 0-7726-1078-9

1. Steelhead (Fish) - Growth. 2. Fish populations - British Columbia - Keogh River. I. Ward, B. R. (Bruce R.), 1952- . II. Berg, Linda, 1957- . III. British Columbia. Ministry of Environment. IV. Title. V. Series.

SH167.T86S52 1990 639.3'755 C90-092062-9

ABSTRACT

Slaney, P.A., B.R. Ward and L. Berg. 1990. A preliminary assessment of the effect of external abrasion on the smolt-to-adult survival of net-pen cultured steelhead trout. Fish. Tech. Circ. No. 88. 11p.

The effect of external abrasion of smolts on the return rate of maiden adult steelhead (Oncorhynchus mykiss) was assessed in a preliminary experiment at the Keogh River in south coastal British Columbia. Abrasion was defined by the incidence of scale loss, fin abrasion and opercular abrasion. Smolts with "low abrasion" (7,300) and "moderate abrasion" (10,300) were marked and released at similar sizes in the lower Keogh River during early May, 1984. Based on population estimates of returning adults in 1986 and 1987, the survivals of the low and moderate abrasion groups were not significantly different: 8.7% and 7.2%, respectively. Both groups returned at similar mean lengths after 2- and 3-ocean years. In addition, recoveries of adults as upstream migrants and downstream kelts combined were examined for differences between the two abrasion groups. Recovery rates from the low and moderate abrasion groups were similar: 4.0 and 4.3%, respectively. Corresponding recoveries of age 2-ocean steelhead were 2.1 and 2.3%, and for 3-ocean fish, 1.9 and 2.0%. The established level of disparity of smolt abrasion was apparently insufficient to cause differential returns of adult steelhead.

ACKNOWLEDGEMENTS

This study was conducted under the auspices of the Federal-Provincial Salmonid Enhancement Program. Release experiments were encouraged by R.A.H. Sparrow, Manager of Fish Culture (to 1987). All sorting and ranking of smolts were carried out by W.L. Harrower; his efforts are appreciated. R.J. Klein also assisted with fish culture at the O'Connor Lake net-pen facility. We also thank the crew at the Keogh River fish fence. An earlier manuscript was reviewed and edited by R.F. Carline and W.J. McNeil who deserve thanks. The latter, in particular, encouraged the authors to continue this research because it attempts to address an important question in anadromous salmonid culture. Suggestions from colleagues E.A. Parkinson and N.T. Johnston were also helpful.

INTRODUCTION

Recent experiments on anadromous salmonid culture suggest that rearing density has a significant effect on smolt-to-adult survival of Pacific salmonids (Fagerlund et al. 1981). Growth rates of salmonids are suppressed at high densities (Reftsie 1977, Fagerlund et al. 1981, Slaney and Harrower 1981, Loftus 1983), and the effect of smolt size on survival has been well-documented (Wagner et al. 1963, Hager and Noble 1976, Partridge 1985, Ward and Slaney 1988).

Associated with reduced growth at higher densities is an increased incidence of scale loss and fin abrasion (Boydstun and Hopelain 1977, Slaney and Harrower 1981). Based on disruption of osmoregulation, Bouck and Smith (1979) reported that a 10% loss of scales induced 50% mortality of coho salmon smolts (Oncorhynchus kisutch) when introduced directly into seawater.

The effect of scale loss and other culture-related injuries on marine survival remains to be demonstrated. The purpose of this study was to provide a preliminary assessment of the effect of smolt condition, as measured by indices of the incidence of scale loss, fin abrasion and opercular abrasion, on the smolt-to-adult survival of hatchery steelhead trout (O. mykiss).

METHODS

Steelhead trout smolts were cultured from eggs of early-run wild fish collected during January to February, 1983, from the Keogh River on Vancouver Island, British Columbia (Fig. 1). Egg incubation and fry rearing were carried out at a small hatchery located on a tributary about 23 km upstream from the river mouth. Fry were graded in hatchery troughs during July and then transferred at a mean weight of 1.3 g into six floating net-pens (3.7 m x 4.9 m by 4.6 m deep) within O'Connor Lake (area 45 ha). Fish were reared to smolt stage using standard automatic feeders (Silver Cup food) suspended over knotless nylon nets, and predators were excluded by exclosures of plastic coated wire screen (Slaney and Harrower 1981).

Average water temperature at a depth of 1 m was 10 C and ranged from 3 C in winter to 20 C in summer. Dissolved oxygen was at saturation, ranging from 8 mg/l to 12 mg/l. Mean density and loading of the net-pens at the smolt stage were 0.1 fish/l and 6-8 g/l, respectively, or 8000 smolts per pen. Further details on net-pen culture of steelhead are available in Slaney and Harrower (1981).

Commencing on April 18, 1984, 20,000 smolts from the pens were hand-sorted into two groups ("low" and "moderate" incidence of

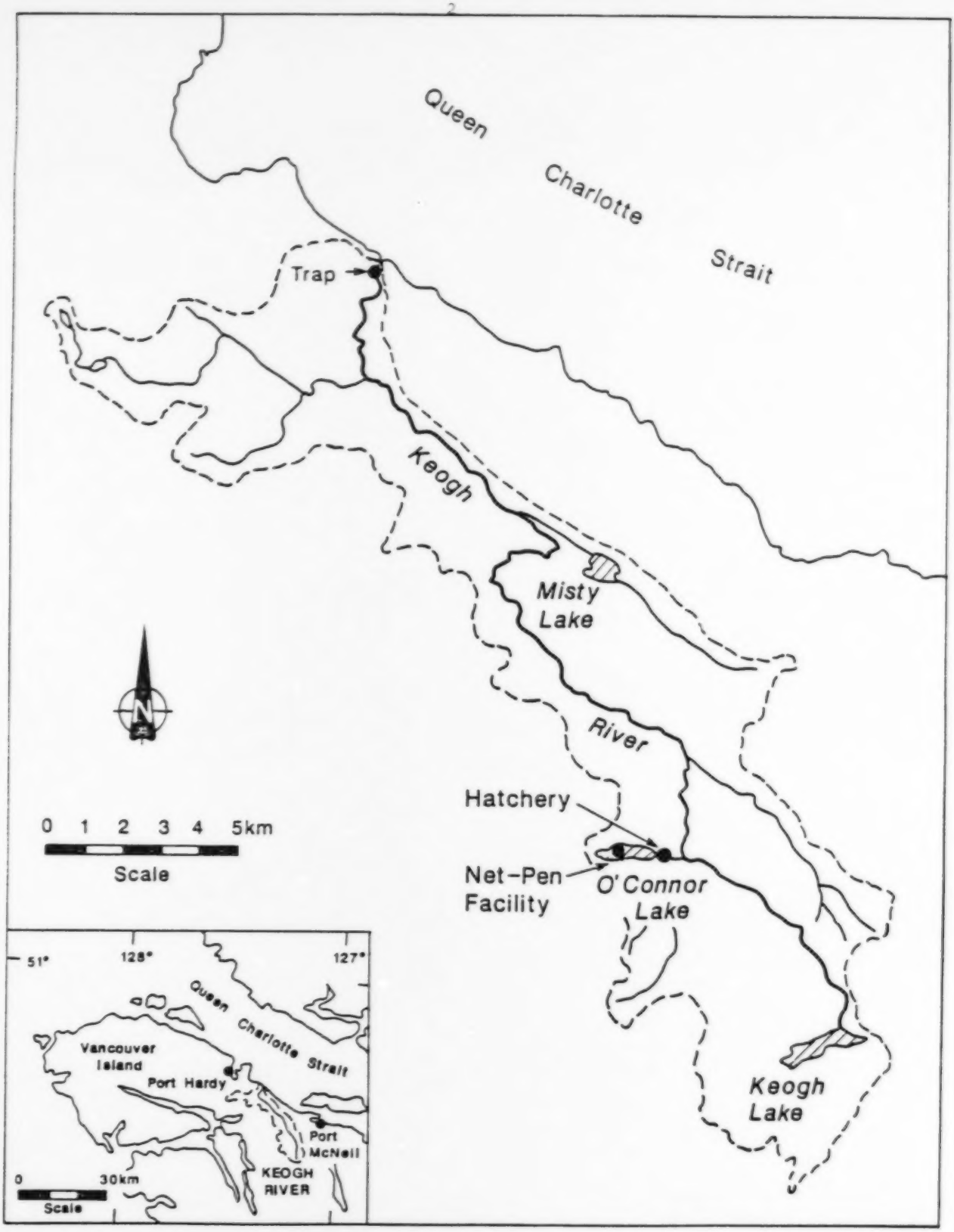

Figure 1. Keogh River watershed showing the location of O'Connor Lake, net-pen facility, hatchery, and adult and smolt trapping facility.

abrasion) by a fish culturist experienced at ranking surface damage of hatchery steelhead smolts. At the same time, very small fish that had not developed into smolts (ca. 10%) were removed from the experimental groups. Smolts with low and moderate abrasions were marked with a left and right maxillary clip, respectively.

We used a ranking system developed by Slaney and Harrower (1981) to document the disparity in degree of abrasion established by hand-sorting into the low and moderate abrasion groups. A random sample (n=70) from each group was ranked, and fork lengths and weights were measured. Scale loss, fin abrasion and opercular abrasion were visually ranked on a scale of 0 to 4 for each fish (Table 1). The sorter estimated the proportion of the body surface, pair of fins and operculum that was abraded, and then assigned the ranking. Standardized drawings were used to improve consistency and accuracy of ratings. The frequencies of the rankings were tested for statistical differences between the two groups by means of a Chi-square analysis (Siegel 1956).

After sorting and marking, each group was held within a separate net-pen for 10 days. Three "bulk" sub-samples (ca. 300 smolts) were collected from each group and weighed to obtain a more accurate estimate of mean smolt weight at time of release. These were compared statistically using the variance from the smaller sub-sample of individual weights (t-test).

Smolts were transported by tanker truck to the release site, 0.3 km upstream of the mouth of the Keogh River and immediately downstream of a fish weir (Ward and Slaney 1988). A total of 10,300 and 7,319 smolts of moderate and low incidence of abrasions, respectively, was released into the Keogh River on May 1 and 2, 1984.

An estimate of the return rates of adult steelhead from the two smolt groups was obtained from the trapping of migrants at the weir from February to May in 1986 and 1987, similar to Ward and Slaney (1988, 1990). Briefly, all upstream migrants were marked with a small hole punched in the operculum, measured for fork length, sampled for scales, and sexed by external features. It was assumed there was no mortality from marking because the hole was small and located at the posterior edge of the operculum. Trapping was not possible during the entire period of migration. Therefore, the number of returning adults from each of the two smolt groups was estimated by mark recapture using the adjusted Petersen estimate (Ricker 1975). Recaptures were obtained by trapping kelts during their downstream migration from March to June in each of the two years of return. Males and females were combined to calculate returns at ocean-age per smolt group. Confidence limits were calculated from marked adults, recaptured kelts and unmarked kelts enumerated during their downstream migration (Appendix II in Ricker 1975). Survivals were calculated as the total returns divided by release numbers; confidence intervals were similarly calculated.

Table 1. Definition of the ranking indices of scale loss, fin abrasion and opercular abrasion used for steelhead smolts reared in net-pens at O'Connor Lake in 1984.

Ranking Index	Scale Loss	Fin Abrasion	Opercular Abrasion
0	0 %	0 %	0 %
1	>0 <1 %	>0 <5 %	>0 <5 %
2	>1 <5 %	>5 <15 %	>5 <15 %
3	>5 <10 %	>15 <30 %	>15 <30 %
4	>10 %	>30 %	>30 %

Table 2. Numbers (No.) and mean weights of steelhead smolts in the moderate and low abrasion groups released into the Keogh River during early May, 1984. (S.D. = standard deviation; n = sample size)

	No. Smolts Released	Mean Weight g	1 S.D. (n)
Moderate Abrasion Group	10,300	63	18.6 (75)
Low Abrasion Group	7,319	72	22.4 (63)

The numbers of adults recovered from each marked group (maxillary clips) were compared. Upstream migrant adults and downstream migrant kelts were summed separately for each smolt group for each year of return. Observed numbers of clip recoveries were compared to expected recoveries by Chi-square analysis (Siegel 1956). For the expected recoveries, equal marine survival of the two smolt groups was assumed.

The number of years spent in saltwater was rechecked from two readings of photomicrographs made from plastic impressions of scales (Narver and Anderson 1974). There were few differences in interpretations of age and spawning history, and these were mediated by the two readers. Repeat spawners were, thereby, excluded from the analyses.

RESULTS

The mean weight of the low abrasion smolt group at time of release was slightly greater (14%) than the moderately abraded group ($P < .05$, Table 2). The length and weight frequency distributions of the two release groups were similar (Fig. 2), although there was a trend towards a bimodal length distribution in the group with the low incidence of abrasion.

Significant differences in the frequencies of external abrasion among the two groups were confirmed for scales, dorsal fin and to a nominal extent, opercula ($P < .05$, Table 3), but not for three other fin structures. Forty percent of the sample from the moderately abraded group had > 5% scale loss and 11% had > 10% loss, whereas none of the smolts in the low abrasion group received these rankings. Similarly, 76% of smolts from the moderately abraded group had > 30% dorsal fin loss, in contrast to only 3% from the low abrasion group. Also, 20% of the former had >5% opercular erosion, whereas there was none at this ranking in the low group. There were no significant differences in the frequencies of caudal and pectoral fin abrasions. However, pelvic fin abrasion was greater within the low abrasion group ($P < .05$, Table 3); 30% (low group) and 16% (moderate group) were > 30% abraded.

The estimated smolt-to-adult survival of 2- and 3-ocean adults combined was 8.7% and 7.2% for the low and moderate abrasion groups, respectively, which was not a significant difference ($P > .05$, Table 4). Because of low numbers of recaptures particularly in the low abrasion group, confidence intervals were wide on the adjusted Petersen estimates.

Numbers of recovered adults, as upstream and downstream migrants with maxillary clips, provided an alternative basis for

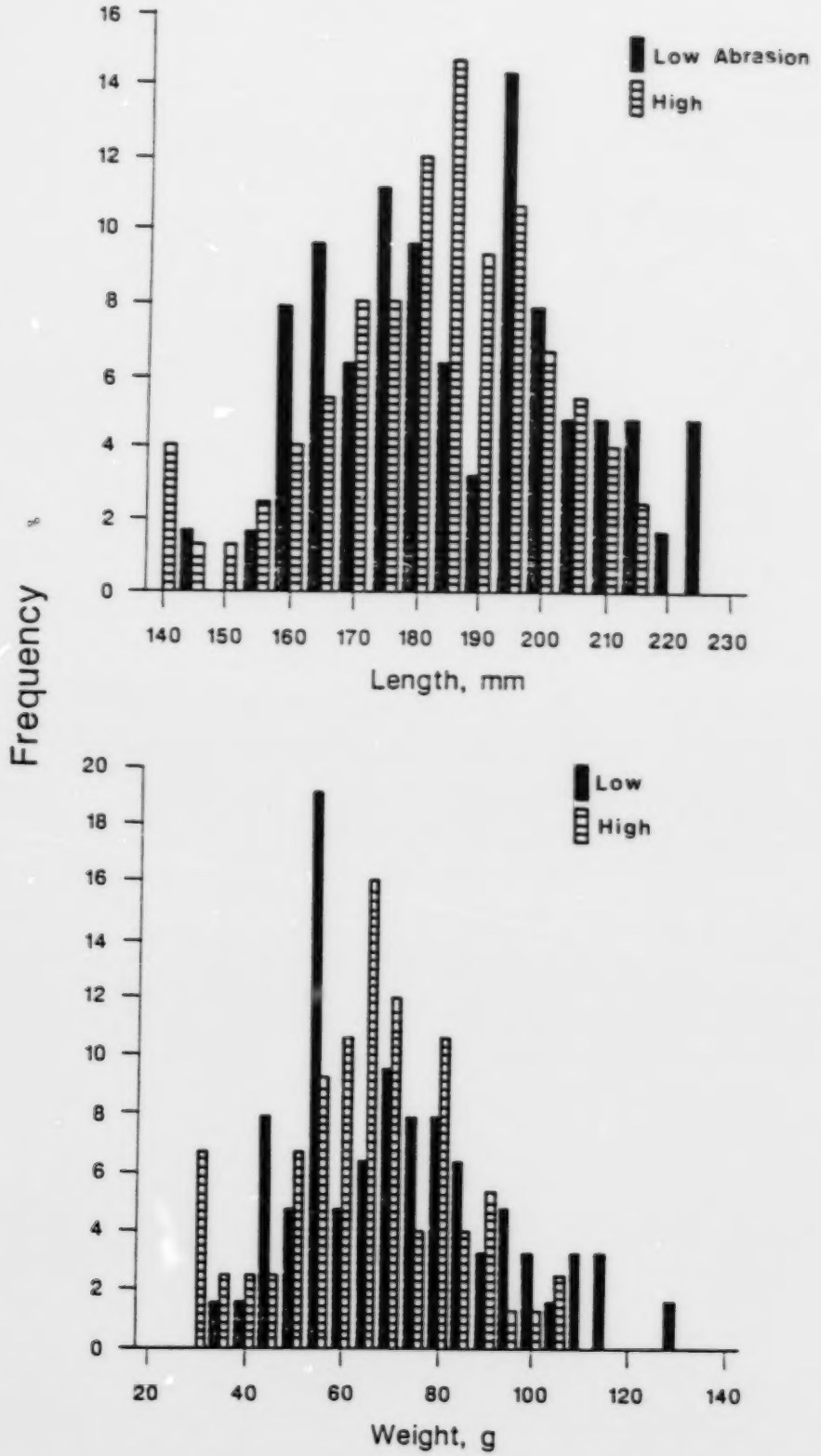

Figure 2. Frequency distribution of steelhead smolt length (top) and weight (bottom) in O'Connor Lake net-pens (April 16, 1984).

Table 3. Percentage frequency distribution of body characteristics of the low (L) and moderately (M) abraded groups of steelhead smolts with respect to index ratings. (An * indicates a significant difference; P <.05.)

	Scale Loss		Dorsal Abrasion		Pectoral Abrasion		Pelvic Abrasion		Caudal Abrasion		Opercular Abrasion	
Index	L	* M	L	* M	L	M	L	* M	L	M	L	* M
0	16	5	8	0	8	9	9	33	2	0	68	49
1	48	23	48	8	43	33	24	31	19	10	29	31
2	36	32	30	7	49	54	5	9	78	79	3	12
3	0	29	11	9	0	4	32	11	1	11	0	1
4	0	11	3	76	0	0	30	16	0	0	0	7

Table 4. Estimated number of returning adults with corresponding smolt-to-adult survivals, and enumerated recoveries of maxillary clipped adults at ocean-age from the low (L) and moderate (M) abrasion groups of smolts.

	Returns of Adult Steelhead				
Group & Age	Population Estimate	Survival Rate %	(95% C.L.)	Enumerated Recoveries	Percent Recoveries
L Total	638	8.7	(6.1-19.3)	292	4.0 %
2-ocean				155	2.1
3-ocean				137	1.9
M Total	738	7.2	(5.8-9.7)	444	4.3
2-ocean				239	2.3
3-ocean				205	2.0

Table 5. Mean lengths at ocean-age of returning adults from the low and moderately abraded groups of steelhead smolts.

	Mean Fork Length (mm)					
	2-Ocean		3-Ocean		Total	
Group	Males	Females	Males	Females	Males	Females
Low Abrasion	658	653	794	750	673	692
Moderate Abrasion	668	652	750	743	678	686

comparison of the performance of the two smolt groups. Observed recoveries of clips did not differ significantly from expected recoveries and, thereby, total recovery rates were similar ($P > .05$; Table 4). Also, recovery rates at each ocean-age were almost identical between the low- and moderately-abraded groups: 2.1 and 2.3% for 2-ocean adults, and 1.9 and 2.0% for 3-ocean adults, respectively (Table 4).

Mean lengths-at-age of adults returning from the two smolt groups were similar ($P > .05$, t-test; Table 5). Also, each sex was similar in mean length-at-age between the two groups ($P > .05$), although there was a low sample size of 3-ocean males.

DISCUSSION

Inadequate smolt quality is one potential cause of the reported lower return rates of hatchery steelhead smolts than wild steelhead smolts of similar size (Parkinson and Slaney 1975, Ward and Slaney 1988, Ward and Slaney 1990). At the Keogh River, the marine survival of several releases of net-pen cultured smolts have typically averaged less than half that of wild smolts enumerated through the weir at the river mouth (data on file, Ward and Slaney 1990). It has been confirmed that "residualism" combined with in-river predation differentially reduces seaward migration of the former (Slaney and Harrower 1981, Ward and Slaney 1990), but culture-related injury is potentially an additive cause of reduced survival.

The results of our study indicate that the degree of external damage has to be more severe than a "moderate" incidence of dorsal fin erosion and scale loss to significantly affect returns. Only a small proportion (11%) of smolts in our test group was estimated to have >10% scale loss, a critical level reported by Bouck and Smith (1979) for coho salmon smolts. Similarly, conspicuous abrasion of the dorsal fin alone may not be a crucial component. A possible difference in the smolt size distributions of the two groups may have also affected the return rates, regardless of the bias to a slightly greater mean weight in the low abrasion group.

Rearing density is typically much higher in conventional hatchery operations than in our study (Leitritz and Lewis 1976), and thus, external abrasion would be more severe than we documented. A high incidence of external abrasion would be expected to result in greater smolt mortality because marine survival is highly size-related in steelhead (Wagner *et al.* 1963, Ward *et al.* 1989). High scale loss, in particular, would reduce growth in seawater because of the higher energy cost incurred in osmoregulation. Smaller smolts within a cohort, in particular, would sustain size-related mortality over a longer period of time.

Additional mortality from reduced saltwater tolerance and disease could also be expected among highly abraded smolts. Bouck and Smith (1979) found that mortality upon introduction of coho smolts to saltwater was a function of the degree of scale loss, but mortality was moderated by acclimation. Novotny (1975) noted that furunculosis, a bacterial disease encountered in freshwater, is often stimulated at time of transfer of salmonids into seawater. Wounds, including severe abrasion of the dorsal fin, would increase the risk of infection. Also, Novotny observed that a loss of scales in chinook salmon (O. tshawytscha) increased their susceptibility to bacterial infection during the first year of saltwater rearing.

Injury of steelhead smolts during culture is common among all rearing techniques (Novotny 1975, Boydstun and Hopelain 1977, Moring 1982), and density is reported to affect the incidence of injury (Boydstun and Hopelain 1977, Slaney and Harrower 1981). In 1983, a comparison was made of the incidence of external abrasion of smolts from four rearing methods in use in British Columbia: rearing channels, net-pens, concrete circulars and fibreglass circular tubs. External injury of steelhead smolts was lowest to highest in the same order, which was probably density related (unpublished data).

Hatchery managers generally attempt to select rearing techniques and densities (and biomass) which improve smolt quality, but they must balance this against smolt production targets. The results of this preliminary experiment suggest that a moderate degree of external abrasion, as in Table 3, has little measurable effect on marine survival. Regardless, we recommend use of cautious practices until this experiment is repeated with greater disparity between abrasion groups and replicated over three years to account for annual variation in the marine environment.

REFERENCES

Bouck, G.R. and S.D. Smith. 1979. Mortality of experimentally descaled smolts of coho salmon (Oncorhynchus kisutch) in fresh and salt water. Trans. Am. Fish. Soc. 108:67-69.

Boydstun, L.B. and J.S. Hopelain 1977. Cage rearing of steelhead rainbow trout in a freshwater impoundment. Prog. Fish-Cult. 39(2):70-75.

Fagerlund, U.H.M., J.R. McBride and E.T. Stone. 1981. Stress related effects of hatchery rearing density on coho salmon. Trans. Am. Fish Soc. 110:644-649.

Hager, R.C. and R.E. Noble. 1976. Relation of size at release of hatchery reared coho salmon to age, size and sex composition of returning adults. Prog. Fish-Cult. 38:111-147.

Leitritz, E and R.C. Lewis. 1976. Trout and salmon culture (hatchery methods). Calif. Dept. Fish and Game. Fish Bull. 164. 197p.

Loftus, K.K. 1983. Effects of rearing density on stress response in tank reared juvenile steelhead (Salmo gairdneri). M.Sc. Thesis. University of British Columbia. 160p.

Moring, F.P. 1982. Fin erosion and culture related injuries of chinook salmon raised in floating net-pens. Prog. Fish-Cult. 44:189-191.

Narver, D.W. and B.C. Anderson. 1974. Fish populations of Carnation Creek and other Barkley Sound streams 1970-1973: Data record and progress report. Fish. Res. Board Can. MS Rep. Ser. No. 1303.

Novotny, A.J. 1975. Net-pen culture of Pacific salmon in marine waters. Marine Fish. Rev. 37:36-47.

Parkinson, E.A. and P.A. Slaney. 1975. A review of enhancement techniques applicable to anadromous gamefishes. B.C. Fisheries Branch. Fish. Man. Rept. No. 66. 99p

Partridge, F.E. 1985. Effect of steelhead trout smolt size on residualism and adult return rates. Idaho Fish and Game, Fishery Research Contract No. 14-16-001-83065. 25p.

Reftsie, T. 1977. Effects of density on growth and survival of rainbow trout. Aquaculture 11:329-334.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191. 382p.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill. 312p.

Slaney, P.A. and W.L. Harrower. 1981. Experimental culture and release of steelhead trout reared in net-pens at O'Connor Lake in British Columbia. p 43-51. In T.J. Hassler [ed.]: Proceedings: Propagation, enhancement and rehabilitation of anadromous salmonid populations and habitat symposium. Humboldt State University, Arcata, Calif.

Wagner, H.H., R.L. Wallace, and H.J. Campbell. 1963. The seaward migration and return of hatchery-reared steelhead trout, Salmo gairdneri, in the Alsea River, Oregon. Trans. Am. Fish. Soc. 92:202-210.

Ward, B.R. and P.A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (Salmo gairdneri) and the relationship to smolt size. Can. J. Fish. Aquat. Sci. 45:1110-1122.

Ward, B.R., P.A. Slaney, A.R. Facchin, and R.W. Land. 1989. Size-biased survival in steelhead trout (Oncorhynchus mykiss): back-calculated lengths from adults' scales compared to migrating smolts at the Keogh River, British Columbia. Can. J. Fish. Aquat. Sci. 46:1853-1858.

Ward, B.R. and P.A. Slaney. 1990 (in press). Returns of pen reared steelhead trout from riverine, estuarine, and marine releases. Trans. Am. Fish. Soc. 120:000-000.